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Reconnaissance

IN THE AREA OF

Turnagain and Upper Kechika Rivers

Northern British Columbia

by

M. S. HEDLEY
and
STUART S. HOLLAND

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Geological map of the Turnagain and upper Kechika Rivers ..... In pocket

RECONNAISSANCE

IN THE AREA OF

TURNAGAIN AND UPPER KECHIKA RIVERS

SUMMARY

1. Kechika and Turnagain Rivers drain an extensive region of the northern Cassiar and Rocky Mountains in northern British Columbia.

2. The Rocky Mountain Trench* separates the Rocky Mountains on the east from the Cassiar Mountains on the west. The high, deeply incised Rocky Mountains of the south dwindle in elevation to low wooded ridges and lose their identity north of Terminus Mountain. The Cassiar Mountains are more irregular and much higher than the Rockies and extend northward beyond the limits of the region.

3. The termination of the northern Rocky Mountains was not caused by greater erosion in that section but by lack of Tertiary elevation.

4. The high central granite range of the Cassiar Mountains has been sculptured by intense alpine glaciation, whereas the Rocky Mountains have been only slightly affected. The Cassiar Mountains show the effects of alpine glaciation with cirque basins formed and some valleys modified. However, the distribution of erratics indicates an eastward movement of continental ice from the Cassiar Mountains across the Trench and over the Rocky Mountains.

5. The drainage pattern in part is normal, and partly exhibits a trellis pattern reflecting bed-rock structural control. Over much of the region the drainage system has resulted from stream piracy on a major scale.

6. A high flanking rock bench on the upper Kechika is the result of pre-glacial stream rejuvenation.

7. The Rocky Mountains are composed of long ranges made up of a great variety of tightly folded sedimentary rocks.

8. The central core of the Cassiar Mountains is a granitic batholith 20 to 30 miles wide and mapped for a length of 100 miles. The flanking mountains are composed largely of sedimentary rocks and a minor amount of volcanics. For

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* Hereafter the Trench refers to the Rocky Mountain Trench.

20 miles north of Sifton Pass the Trench is underlain by Upper Cretaceous or early Tertiary conglomerate, north of which the Trench is floored with glacial drift and alluvium. South of Dall Lake the Cassiar batholith is flanked by schists and gneisses formed by the action of numerous pegmatites, elsewhere there is little or no contact metamorphism.

9. All the soft argillaceous rocks are highly cleaved, and contorted by drag-folding.

10. The Trench is a boundary across which it has been impossible to make lithologic correlation between the two different mountain systems. The Rocky Mountain structure comprises regular, steeply-dipping, tightly compressed folds. Folding in the Cassiar Mountains is more irregular, the structural trend is different from the Rocky Mountains, and the folds are interrupted by cross-warps and are complicated by drag-folding, thrusting and some overturning to the east. The core of the system is the Cassiar batholith, some 20 to 30 miles wide.

11. Placer-gold deposits have been worked on Wheaton and Walker Creeks. The country has not been thoroughly prospected but exploration on other creeks should be governed by the knowledge already gained.

12. A few lode deposits are known but none has undergone any development. A section near Dall Lake radial to a bulge in the eastern contact of the batholith is considered the most favourable lode prospecting area.

INTRODUCTION

The upper Kechika and Turnagain Rivers together drain a region greater than 6,000 square miles in extent in northern British Columbia (see key map). They unite, as the Kechika, to form a major tributary of the Liard River. Kechika River heads at Sifton Pass, latitude 58 degrees north, and flows north-westward in the Rocky Mountain Trench along the flank of the northernmost Rocky Mountains. Turnagain River heads on the west flank of the Cassiar Mountains and cuts across them in a general north-easterly direction to join the Kechika at Chee House, an abandoned trading post, about 70 miles from Liard River and 60 miles due south of the Yukon boundary.

During 1939 topographic mapping of the Trench by the Department of Lands was completed from Finlay Forks to Sifton Pass, and in addition triangulation was almost completed from Sifton Pass to Lower Post on Liard River, a few miles south of the Yukon boundary. This work was continued, at a reduced rate, in 1940; the Trench was mapped as far north-west as Gataga and Terminus Mountains. Triangulation was completed to the Yukon boundary and extended up Turnagain River to within 25 miles of an existing network to the east of Dease Lake.

The authors travelled with the two survey parties from Prince George, using their base camps as headquarters from which fly trips were made during the greater part of the season. M. S. Hedley so travelled with the topographic party under the direction of N. C. Stewart, as far as the mouth of Gataga River. In September he and his assistant were transported up Frog River by boat to the first main fork and from there they proceeded on foot by way of Jackstone Creek and Dall River to the upper Turnagain River. S. S. Holland started with the triangulation party under the direction of H. Pattinson, commenced work at the mouth of Gataga River, and progressed down river to Chee House and then westward by way of the Mosquito Creek trail to Wheaton Creek. The authors returned to the coast by way of Dease Lake and Telegraph Creek.

Topography of a strip 10 miles wide, centering on Kechika River, was obtained from vertical aerial photographs taken during the season. These, together with horizontal photographs of the strip between Sifton Pass and Gataga Mountain, were furnished through the courtesy of the Department of Lands and greatly facilitated work both in the field and in the office. Topography lateral to the photographed strip was sketched in the field and controlled by the triangulation network. All topography on Turnagain River was mapped in this

fashion. Elevations of most peaks other than those occupied by triangulation stations have been calculated by photo-topographic methods. N. C. Stewart was consistently helpful during the course of the office work. The topography at the head of the Turnagain is compiled from: (1) Map 381-A of the Department of Mines and Resources, Ottawa: (2) a sketch map published in 1933 by Mandy*; (3) a map published in Bulletin No. 2, 1940 of the Department of Mines, British Columbia.

The writers wish to express their thanks to Messrs. Stewart and Pattinson for assistance in the field, especially the former, who altered his plans in the latter part of the season to make the overland trip more feasible. S. D. Townsend and R. G. McEachern gave admirable assistance throughout the season.

Access and Means of Travel

The region is so large that only the established routes into it may be mentioned, particularly as little or nothing is known of other possible routes. That followed on the journey in 1940, is from Prince George. Regular travel is over the waterways from Summit Lake, 32 miles north of Prince George via Crooked, Pack, Parsnip and Finlay Rivers to Ware. The distance to Ware, the Hudson's Bay Company post on Finlay River, is 350 miles and the trip can be made by boats carrying a pay load of 2 1/2 tons. The only hazardous section on the Finlay is Deserters Canyon; it cannot be navigated in high water and is half a mile long. From Ware a pack-trail follows the Fox River 44 miles northward to Sifton Pass. Fox River is navigable with difficulty, for a distance of 23 miles in a straight line, from above a short portage close to the mouth.

The other principal route is from Telegraph Creek, the head of navigation on Stikine River and served regularly by river-boat during the open months from about May 15 to October 15. A branch road leads from Telegraph Creek to Dease Lake, a distance of 72 miles. From there a pack-trail and winter road extends eastward to Wheaton (Boulder) Creek, a distance of 45 miles.

A fair pack-horse trail extends throughout the region, following the east side of the Trench from Ware on Finlay River to the river-crossing at Chee House, thence to Lower Post on Liard River. Another trail, in parts not very well located or cut out, extends from the mouth of Turnagain

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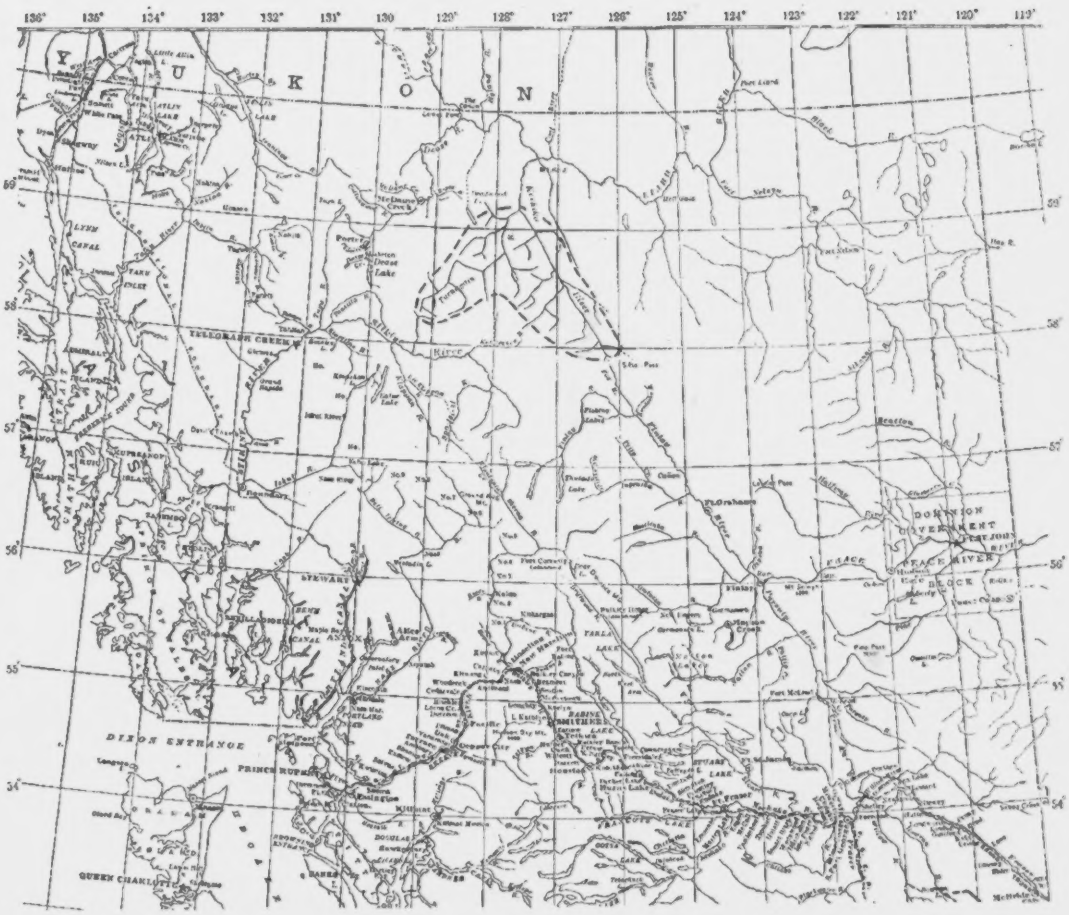
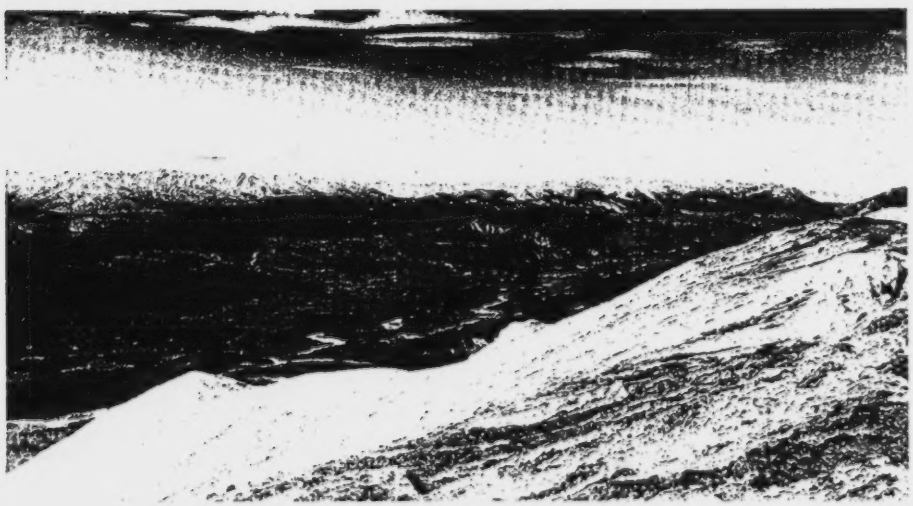
* Ann. Rept., Min. of Mines, Brit. Col., 1933 pt. A.



Key Map of northern British Columbia showing region outlined by heavy broken lines.

Plate I.

A. Looking south across the Rocky Mountain Trench towards the Cassiar Mountains. Sifton Pass is in the middle distance and Fox Lake lies to the left. Note the bench flanking the heads of Kechika and Fox Rivers. A fault scarp lies along the base of the mountains in the left distance.



B. Looking north-west from near Driftpile Creek. Note the area of bench land between the Trench and the through-valley that continues in mid-distance. Valemont Mountain is near the right margin.

River up Sand and Mosquito Creeks to the upper Turnagain and connects with the trail to Dease Lake. A branch of this trail leads from Deadwood Lake to McDame on the Dease River. Another pack-horse trail leads east from the Kechika valley at the mouth of the Turnagain towards Fort Nelson. There are no other recognized pack-horse trails and few foot-trails other than those used by Indians and by trappers during the winter months.

There are fragmentary trails on the Turnagain River, Indian trails that lead from Deadwood Lake to Dall Lake, and a reported trail from Dall Lake to Jackstone Creek. Horses lightly loaded with narrow packs could be taken over most of these trails, but only after some clearing. The major valley-bottoms and the bottoms of through-valleys afford reasonably good going and sufficient feed, but canyon sections should be avoided. Travel in the Rocky Mountains south of Terminus Mountain is difficult owing to the fact that the tributary valleys flow in canyons adjacent to the Trench.

In 1934, E. C. W. Lamarque, who was scouting a route for the Bedaux expedition, travelled with an Indian and three horses from Sifton Pass to Dease Lake. His route extended up Ludwig Creek to a through-valley abreast of the third lake on that stream, thence across upper Rainbow River to Frog River, up Jackstone Creek to the edge of the granite and thence westerly to the head of Flat Creek on the upper Turnagain. Horses were also taken by Lamarque south-eastward from Ludwig Creek to Fox Pass by following valleys roughly parallel to Fox River. In 1939 he also blazed a trail from Chee House southward on the west side of the Kechika valley.

Horses cannot be obtained in the district. Those used by the survey parties during 1939 and 1940 were driven overland from Fort St. James. Horses may be obtained at Telegraph Creek and driven to the upper Turnagain, a distance of about 120 miles.

The Kechika River is navigable by boats of the type built at Summit Lake and in use on the Parsnip and Finlay Rivers. Two such boats 36 feet long, built from whipsawn lumber at the mouth of Driftpile Creek in 1940, and equipped with 16-horse-power motors, were in use during the 1940 season. Navigation is difficult even at high water above Big Creek, and is impossible above Driftpile Creek. The crooked channels and numerous drift-piles on the Kechika make boating difficult, but not too hazardous for skilled men. The lower river, in the general neighbourhood of Scoop Lake, is easily navigable.

Gataga River was ascended 15 miles without difficulty in

1940. It is reliably reported that the canyon 8 miles farther up-stream is passable and that a boat can be taken through it and a number of miles beyond. Frog River was ascended easily on September 1st as far as the main fork and with difficulty 3 miles farther up Jackstone Creek, which is smaller than the main stream. No boat was taken up the Turnagain and the river was not followed throughout on foot so the question of its navigability is not known. Judging from the amount of water, the observed sections of the river and the grade, it seems possible that boats could be taken as far up as the mouth of Cassiar River at favourable stages of water.

The larger lakes make good landing for airplanes, notably Deadwood, Dall, Scoop, and Denetiah Lakes. An airplane has landed on the lake east of the upper Frog River, and landings could be made on Spinel Lake, the lake north of Davie Creek, the lakes on Ludwig Creek, and those at the head of Moodie Creek. Deadwood, Dall and Scoop Lakes are, however, the only ones where low clouds would not make flying dangerous, and the other mountain lakes should be approached only when visibility is good.

Stretches of the lower Kechika River might serve as landings, and there is one wide, straight stretch a mile or two below Gataga fork, but driftwood makes landing hazardous whenever the river is high.

Freight can be shipped from Summit Lake to Ware for $150 a ton. From Wrangell, Alaska, freight can be landed at Dease Lake for $120 a ton and from Dease Lake to Wheaton Creek can be flown in for $100 a ton. Food and general supplies may be obtained at Prince George, Ware, Telegraph Creek, Dease Lake and Lower Post.

Historical Notes

Fur traders were the earliest explorers of the region. In 1834 J. McLeod of the Hudson's Bay Company ascended the Liard from old Fort Halkett, travelled up the Dease River to Dease Lake and crossed over to the head of the Stikine.

In 1824 Samuel Black of the Hudson's Bay Company explored the headwaters of the Finlay. He records in his diary when he passed the mouth of what is now known as Fox River that it heads at a pass two days travel northward, whence a river flows northward into the Liard. This pass was subsequently named Sifton Pass by Inspector Moodie of the Royal North-west Mounted Police. Nothing however was known of the Kechika and Turnagain Rivers until many years later.

Placer-gold was discovered on Dease Lake in 1873 and in the ensuing few years the many miners and prospectors in the country spread far afield. Placer was found on Walker Creek in 1877 and by 1886 several parties of prospectors had gone into both the Turnagain and Kechika basins.

A trading post was operated by Sylvester at Chee House in 1887, as well as a "Lower Post" on the Liard, but it is not known when these were established. Supplies for Chee House were packed in with horses from McDame, then known as Sylvester's Upper Post.

For many years there is no record of any but random trappers and prospectors having visited the region. In 1924 after a discovery of gold on Goldpan Creek, prospecting again reached the headwaters of the Turnagain and in 1932 claims were staked on Wheaton (Boulder) and the nearby Bullion, Hall and Faulkner (Palmer) Creeks. Since then there has been some placer-mining activity, including a drag-line operation on Wheaton Creek started in 1938.

In 1898 Inspector J. D. Moodie of the Royal North-west Mounted Police passed through the Kechika valley on a trip from Edmonton to the Yukon. His route was by way of Fox River and Sifton Pass, thence down the Kechika. He crossed the Turnagain near the mouth of Sand Creek, travelled along the existing trail to Deadwood Lake and from there to McDame. His report is the first authoritative description of the region.

No geological work was done in the region prior to 1940, with the exception of the Turnagain River headwaters. In 1887 G. M. Dawson went down Dease River and ascended the Liard and Frances Rivers en route to the Yukon, and in the same year R. G. McConnell descended the Liard to the Mackenzie. Geology of Dease Lake was studied in 1925 by Kerr and Johnston and from the head of the Turnagain to McDame in 1935 by Hanson and McNaughton. Mandy reported on the placer creeks at the head of the Turnagain in 1933. Holland studied the placer-deposits and bed-rock geology at and near Wheaton Creek in 1939.

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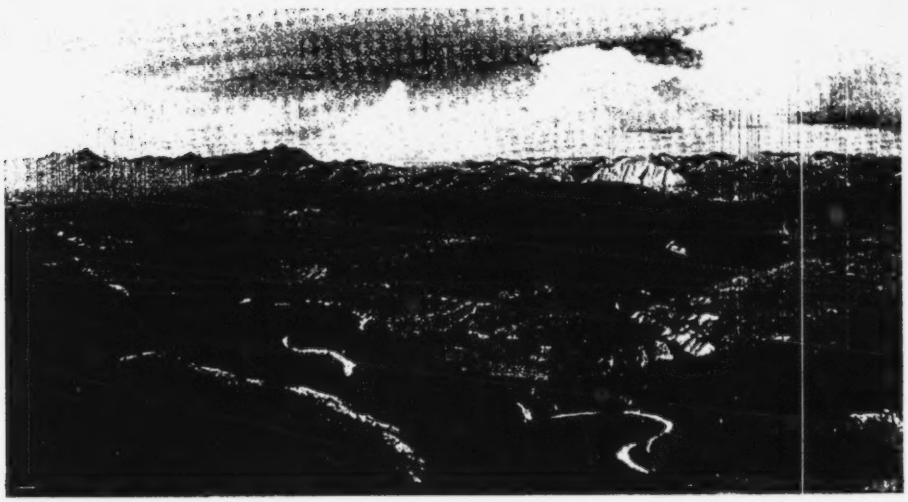
S. S. Holland: Bull. No. 2, B. C. Dept. of Mines, 1940.

Plate II.

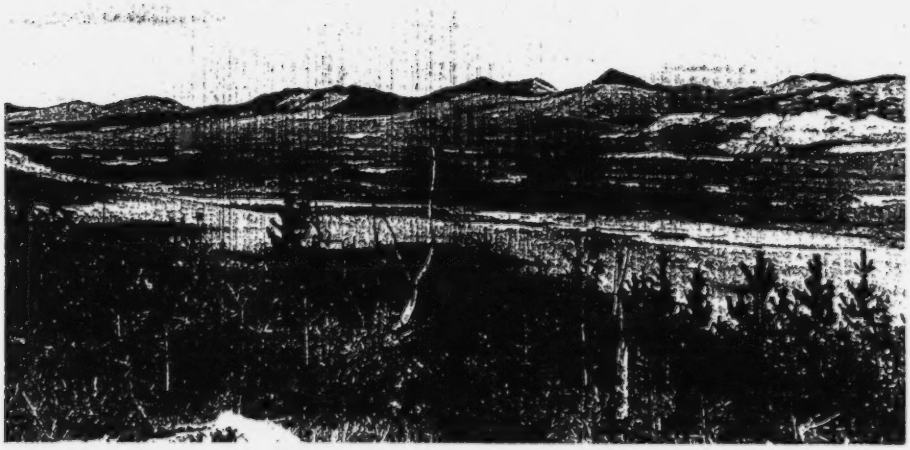
A. Looking south-eastward up Kechika River from Valemont Mountain. Mount New in centre distance. Note the bench developed in the bottom of the Trench.



B. Looking northward across the Trench from Valemont Mountain. Note the canyon at the mouth of Forsberg Creek. Gataga River valley is seen beyond ridge in distance, Brownie and Gataga Mountains in left distance.

Plate III.

A. Looking north across the Trench towards Gataga Mountain from a point near the mouth of Frog River. Note the bold front of the Rocky Mountains at this point.



B. Looking north-east across the Trench from a point west of Terminus Mountain. The valley at this point is wider, the mountains much lower, and the front more subdued than in the above picture taken some 20 miles to the south.

PHYSICAL FEATURES

The region takes in part of the country between latitudes 58 and 59 degrees north and longitudes 126 and 129 degrees west. It includes some western ranges of the Rocky Mountains and extends almost completely across the Cassiar Mountains. Between these two mountain systems is the Rocky Mountain Trench (see Plates I and II). From Sifton Pass at latitude 58 degrees north the Kechika River flows north-westward in the Rocky Mountain Trench beyond the mouth of the Turnagain River. The Fox River flows south-eastward in the Trench from the same Pass which is one of the major divides in this remarkably long, straight valley that flanks the western front of the Rocky Mountains and continues beyond the northern extremity of those mountains. In the region, the Trench is a dividing line, physiographically and geologically, between the Rocky Mountains to the east and the Cassiar Mountains to the west.

The region is mountainous and for the most part deeply incised. All major summits are 6,500 feet or more in elevation and a few in the granite ranges in the western part exceed 8,000 feet. From Sifton Pass, elevation 3,273 feet, the Kechika drops to an elevation of about 1,900 feet at the mouth of Turnagain River, a distance of 100 miles. The Fox River drops 800 feet in 44 miles to join Finlay River at Ware. Turnagain River, at an elevation of 3,450 feet at the western margin of the region, drops 1,550 feet in a distance of 105 miles to its mouth.

The Rocky Mountains consist of parallel structural ridges that wedge out at an acute angle against the Trench. The general summit level is in excess of 6,000 feet in elevation, and reaches a maximum in Brownie Mountain, elevation 7,595 feet. The mountains are deeply incised, particularly in the section abreast of Sifton Pass. Driftpile Creek enters the Trench through an impassable gorge and most of the smaller streams are bounded by precipitous walls that rise to the very summits. The range just east of Gataga River is extremely rugged and 5 miles east of the river rounded ridges attain elevations of about 7,000 feet. This high western range of the Rocky Mountains ends at Terminus Mountain (see Plate III) and the inner ranges, which for some miles to the south-east have become progressively lower and more subdued in outline, dwindle to the north-west into timber-covered hills and low ridges separated by wide, swampy valleys (see Plate IV A).

Terminus Mountain marks the north-westernmost extremity of the Rocky Mountains, beyond which the summit level de-

creases to between 3,500 and 4,000 feet at a point east of Chee House. In this section the valleys flare widely and their timbered slopes extend to comparatively low summits. Except where the major creeks flow through canyons as they enter the Trench, the valley bottoms are wide and often swampy.

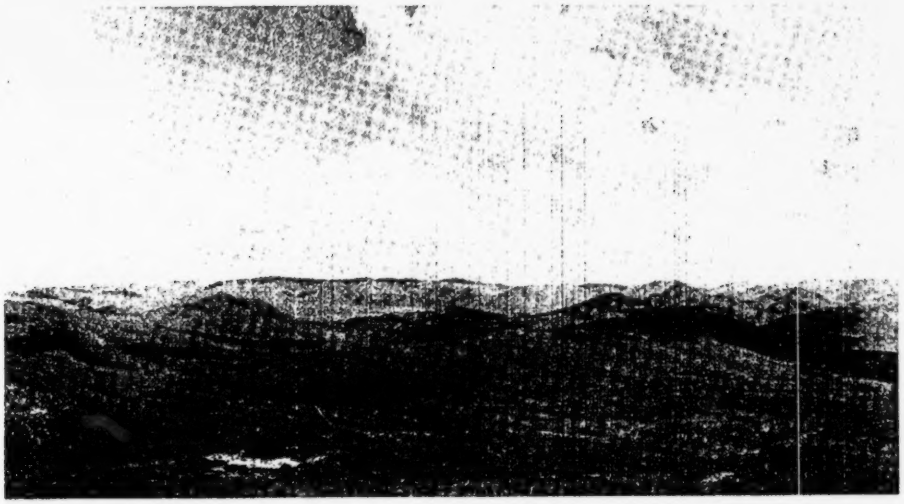
The Cassiar Mountains are structurally less uniform, and are subdivided by broad-bottomed, deep valleys, some of which are through-valleys. They are higher than the Rocky Mountains and less regular; a number of peaks in the eastern ranges are 7,000 feet in elevation or more, and the peaks in the granite ranges are about 1,000 feet higher. The highest peak in the district, at the head of Ludwig Creek, is 8,900 feet in elevation, and Shark Tooth Mountain, south of the Turnagain is 8,765 feet. The unbroken front along Fox River gives way at Sifton Pass to an irregular bench-like area (see Plate I B) widening to 5 miles at lower Rainbow River, north-westward of which rises a prominent limestone range. Another bench-like area about 4 miles wide lies to the east of Mount Winston and out of it a range rises to 5,600 feet, extends north-westward beyond Turnagain River, and presents a straight unbroken front on the Kechika side. Beyond Mount Winston, however, the eastern ranges are less rugged and their summits decrease to about 5,000 feet north of the Turnagain. In that section there are many long ridges parallel to the structural trend of the underlying formations.

The Cassiar Mountains culminate in the granite ranges, west of which they are less rugged and less deeply incised. In the section of the upper Turnagain River, although the general level is high (King Mountain 7,914 feet) there are large, poorly incised masses and long upland slopes. There is a marked contrast on the Turnagain between the wide, flaring valley with its interlocking spurs west of Three Forks Creek (see Plate VII) and the deep, almost gorge-like valley east of the Cassiar River.

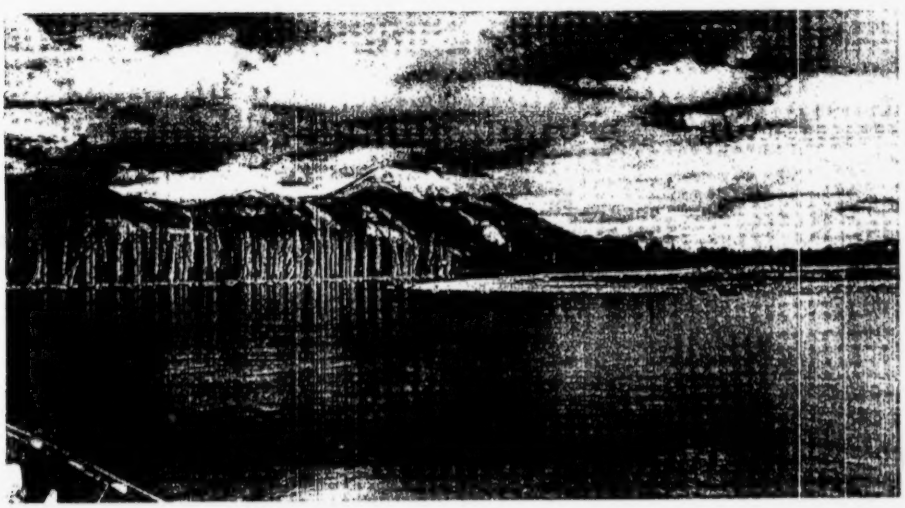
There are many small glaciers in the granite mountains. They appear to be stagnant and not actively eroding their beds, because streams heading in that section are nearly all clear. The amount of ice diminishes to the north-west and is very small near the Turnagain valley; one small patch of ice on King Mountain and another south of the head of Mosquito Creek are the only glaciers, and none are reported to the north-west, as far as Dease River.

There are no glaciers in the Rocky Mountains within the region. The nearest is a large ice-field on Lloyd George Mountain at the head of Gataga River.

Plate IV.



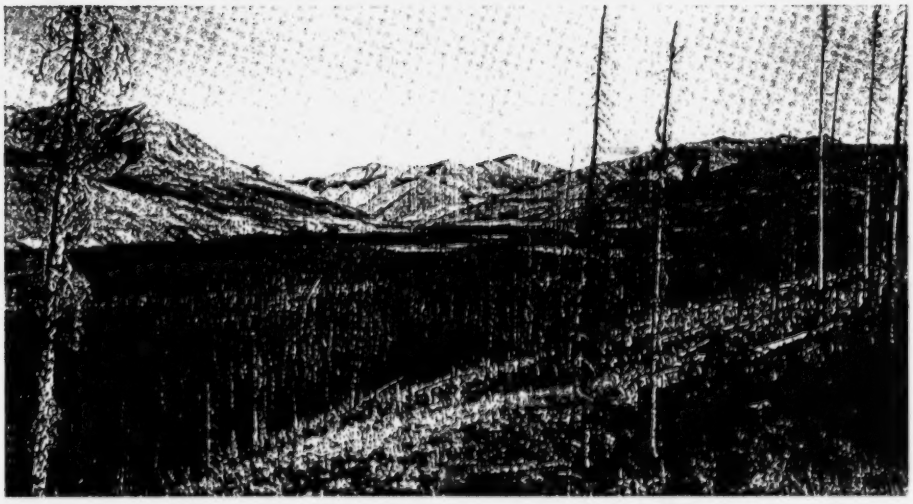
A. View looking north-eastward across the continuation of the Rocky Mountains from a point 15 miles north-west of Terminus Mountain.



B. Kechika River, looking south-eastward towards Terminus Mountain.

Plate V.

A. Looking west towards the granite ranges at the head of Dall Lake.



B. Turnagain River valley, looking north. Dall River enters short of the low hill on the right.

Glaciers have been at one time more widespread, and the effects typical of ice erosion are seen over a larger area than that in which existing glaciers occur. Cirque basins, hanging valleys, truncated spurs, gravel-filled valley-sections alternating with canyons, pot-hole lakes, and morainal piles are seen from Fox River and the flanking range south-west of Sifton Pass, through the upper waters of Rainbow and Frog Rivers to the mountains west of Dall River (see Plate V A) and the upper basin of Mosquito Creek (see Plate VI B). East of this general line there is little evidence of ice erosion and only a few small cirques are seen, notably on the east side of Mount Winston and along the east side of the same range to the north-west. This seems to mark the former maximum extent of intense alpine glaciation. In the Rocky Mountains a few small cirques point to former alpine glaciers on the east side of Gataga Mountain and other high mountains nearby, but none of the valleys appear to have been modified by glacial erosion.

Accumulations of glacial drift are widespread but are prominent only in a few places, notably in the Fox River valley and in the angle between Kechika and Gataga Rivers. The lower Kechika valley is filled with drift but most of this has been stream-sorted, so that hummocky terrain and pot-holes are local only. Elsewhere the mantle of drift is thin and discontinuous. Moraines, in the form of irregular bottom-filling, high-level semi-benches and plasters on the hillsides, and lateral ridges along the walls are seen locally in the lower valleys of Frog and Gataga Rivers, as well as in the Turnagain River valley. Turnagain valley, above Kutcho Creek is deeply filled with drift in which there are many pot-holes. Glacial erratics are widespread and granitic boulders are seen not only in the front ranges of the Cassiar Mountains but in the Rocky Mountains as well; some are as far east as Rabbit River.

The drainage forms a trellis work pattern bordering the Trench. This is most pronounced in the Rocky Mountains but is obvious also in the Cassiar Mountains as far west as Dall River. North of Terminus Mountain in the more or less uniform slate belt it is less obvious, whereas west of the granite, in the section of the upper Turnagain River, the drainage does not present a uniform pattern. Kechika and Fox Rivers follow straight courses along the Trench, but Turnagain River valley cuts through the mountains in a number of prominent bends. The valleys of lower Frog and Gataga Rivers as well as that of Moodie Creek are straight.

The Rocky Mountain Trench is 4 to 9 miles wide along Finlay River south-east of the region. It is constricted along the Fox and upper Kechika Rivers to a width of 1 1/2 to 2 1/2 miles and widens to about 4 miles at Gataga River.

North-west of Terminus Mountain it widens again, rather abruptly, to between 6 and 7 miles. In the section at Chee House the north-eastern margin is indistinct and farther to the north-west it is more so.

All tributaries of the Kechika River, with the exception of the three large rivers, enter the valley through canyons (see Plate II B). The canyons are most pronounced in the upper Kechika section, being cut through a general bench-level, but in the lower river the tributaries also flow in canyons at the margins of the Trench.

Between Fox Lake and Kechika canyon the Trench is incised to a depth of about 400 feet across about one half its width. This incision, with its flanking rock and gravel benches, is one of the most distinctive features of the region (see Plate II). The bench-level is developed almost exclusively on the eastern side of the Kechika and is not seen north of the canyon. It is a rock bench almost completely covered with stream-deposited gravels that have filled all irregularities in the former rock surface. Locally the gravels are semi-cemented so that erosion produces bold cut-banks and, as at the mouth of Driftpile Creek, striking hoodoos. The bench-level slopes slightly towards the valley and has the same longitudinal grade as the present stream.

Frog River enters the Trench at grade as a meandering stream in a deep, straight gorge. Gataga River has a short canyon-section 23 miles from the mouth, but enters at grade through a wide, straight valley. Turnagain River, from abreast of the head of Mosquito Creek to its mouth, flows in a deep, narrow valley that in places might be classed as a gorge. Two canyon-sections on the Turnagain, one just above the mouth of Kutcho Creek and one just above the mouth of Cassiar River, together lower the river about 500 feet.

The streams generally throughout the Cassiar Mountains are characterized by abrupt changes in grade and by hanging relationships of some members. These effects are not all the product of glaciation, as will be shown in the next chapter.

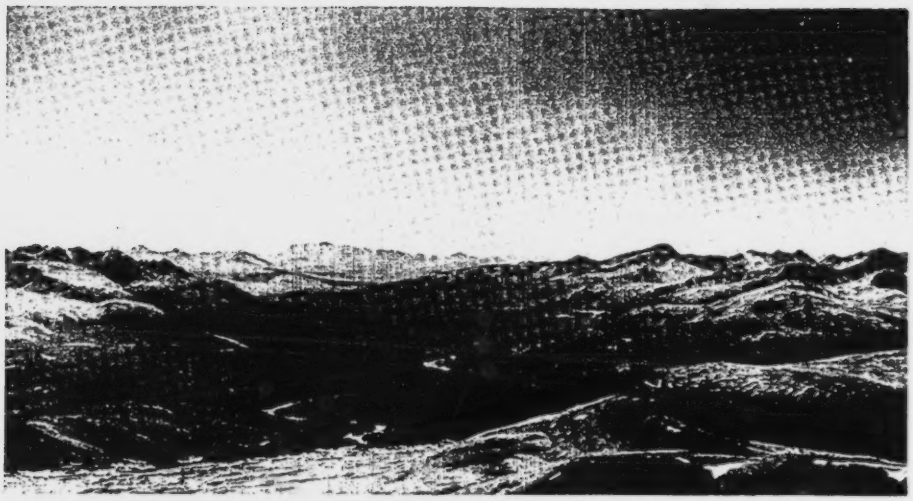
There are several remarkable through-valleys. One in the Rocky Mountains observed to be at least 40 miles in length, is crossed by Driftpile and Big Creeks and contains streams that flow from low divides northerly and southerly to join the larger crosscutting streams or simply to break through the ranges to join Kechika and Gataga Rivers. The most remarkable through-valley west of the Trench starts as a bench at Sifton Pass and extends past Dall Lake, across Turnagain River to Deadwood Lake. This valley is cut into and across

Plate VI.

A. Looking south-eastward along the through-valley towards Dall Lake from a point near the divide between the south fork of Mosquito Creek and the Turnagain. Turnagain River flows from right to left and comes through the mountain front in the middle distance.

B. Looking south-east across the valley of Mosquito Creek at the divide near its head. The high mountain on the left is 7,600 feet elevation. Note the cirques on the eastern side of the peaks. The rock in the middle ground is granite.

Plate VII.



A. Looking south-westward up the valley of the upper Turnagain River from the head of Mosquito Creek. Note the interlocking spurs in the widely-flaring valley. King Mountain is on the skyline to the left of centre.

B. Looking north-eastward down the valley of the upper Turnagain from Wheaton Creek. Kutcho Creek comes in from the right in the middle distance and the Turnagain swings sharply to the left behind the high mountain on the skyline. The mountains on the skyline to the right are granite.

by the present drainage, but the former, broadly-flaring outline is still to be seen, incised to depths ranging from 100 feet by minor streams to 1,000 feet or more by major streams (see Plate VI A). Other, less continuous through-valleys farther to the west extend from Finlay River headwaters into the granite ranges.

The country is for the most part heavily wooded, the kind and density of growth varying with soil and amount of precipitation. Spruce grows everywhere except on the larger gravel flats; pine is abundant on gravel flats of the lower Kechika and poplar is found everywhere at elevations below 4,000 feet. Birch grows sparsely in the lower Kechika and Turnagain valleys and in the valley of Mosquito Creek. A few tamarack trees were seen at Scoop Lake. Willow and alder grow on the slopes to timberline and scrub birch is found at and near timberline throughout the region. Timberline is between 5,000 and 5,200 feet, and is somewhat lower in the north-westernmost part of the region.

Yearly precipitation varies with the locality, but with the exception perhaps of the granite ranges, is nowhere particularly heavy. There is a marked decrease in precipitation north of Sifton Pass, both in rain and snowfall. The snowfall at Sifton Pass is said to average between 3 and 5 feet on the ground and to lessen towards Gataga fork, north of which the average fall is less than 1 foot, and the ground is apt to be bare of snow during most of the winter months. By mid-July there is still sufficient snow to hamper field work at higher elevations about Sifton Pass, but farther north there is snow only on the highest summits by that date.

On the lowest slopes of the Rocky Mountains north of Kechika canyon and on some flats north of Terminus Mountain there is semi-dry belt vegetation such as open patches of grassland, groves of aspen, and a considerable amount of thyme and juniper. In this latter section 30 head of horses were wintered in 1939-40 without hay. Similar conditions exist in lower Dall and lower Turnagain River valleys.

Winters are reported to be cold, but the summers are warm. In 1940, at low to moderate elevations, there were no frosts in July and August and the lower Kechika valley was said to be completely bare in April. The summers, however, are not altogether pleasant, and in July, 1940, there were only 4 warm, sunny days. Local showers fall almost daily and an observer on a high summit sees constantly moving clouds and numerous rainstorms in every direction. Wind blows almost incessantly on the summits and can be piercingly cold even in mid-summer. The wind is not steady and does not always

blow in the same direction as in the valleys. It is likely that these crosswinds cause the constantly changing cloud patterns and the local rainstorms.

Game is sufficiently abundant to supply the needs of any travellers. Moose are found in all sections but are not numerous, and appear to have been greatly hunted in recent years. Caribou are scarce in the summers but are reported to winter in large numbers on Rabbit River and to migrate to and from the summer feeding grounds on the west flanks of the Cassiar Mountains. Deer are occasionally seen and bear are fairly numerous.

Sheep and goat are found in the Rocky Mountains between Driftpile Creek and Terminus Mountain. In the Cassiar Mountains they are found from Valemont Mountain north-west and west on the eastern side of the granite. One band of 70 sheep was seen near Gataga Mountain.

PHYSIOGRAPHY

There are many physiographic features of importance and interest, the full explanation of which would be an extremely valuable addition to the formative processes of a large section of northern British Columbia. This reconnaissance makes it possible to mention only the more general features and to outline possible explanations.

Rocky Mountains

There remains some doubt as to the actual limit of the northern Rocky Mountain structure, but there is no doubt that the ranges become lower in elevation and eventually lose their identity (see Plates III and IV A). The present writers did not examine the country beyond Chee House, but on days of good visibility it was possible to see many miles north and east. From long range observation, from elevations determined by the triangulation survey, and from the old reports, the following seems to sum up existing knowledge.

The eastern front of the Cassiar Mountains continues far to the north-west, although perhaps with a general lowering in elevation. The front is continuous west of Lower Post, through the lower great bend in the Dease River and is, according to Dawson*, about 25 miles from the mouth of Frances River. The Rocky Mountains however, do not persist as the series of bold, high ranges characteristic of the country near the upper Kechika and Gataga Rivers.

The western ranges of the Rocky Mountains become progressively lower north of Terminus Mountain, and lose topographic identity somewhere south of the Liard. McConnell noted in his reconnaissance of the Liard that the only range of the Rocky Mountains that reaches the Liard was at Vents River, and that this high limestone range dwindles rapidly as it approaches the river from the south-east and almost disappears topographically within a few miles north-west of the river. The country south of Liard River from the mouth of Vents River to Terminus Mountain, east of the front of the Cassiar Ranges, and north of the Liard for some miles in this same section, is a region of rounded timbered hills and low, undulating plateau with no prominent or distinguishable mountains.

The structure of the Rocky Mountains is probably continuous and the same rocks extend to and past Liard River, but

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* Geol. Surv., Canada, Ann. Report, Vol. III Pt. 1, 1889.

through a low, plateau-like region averaging 300 to 500 feet above the river. Some hills may rise about 500 feet higher or to maximum elevations of about 3,500 feet.

The country north of the Liard in this section is not explored, but two mountain ranges are known on the lower Frances River, the Simpson Range on the west and the Tses-i-uh Range on the east, which are on the line of continuation of the western ranges of the Rocky Mountains. The western flanks and roots of these mountains are buried beneath rocks which were assigned by Dawson to the Tertiary, and which occupy a basin of unknown extent. Dips are as steep as 20 degrees on Frances and Liard Rivers and deformation has apparently been much less than in the Sifton formation. Whether or not these rocks are the same age as the Sifton formation is unknown, but there has certainly been far less deformation in the north-western basin. The rocks of the Simpson and Tses-i-uh Mountains are schist and limestone, rocks originally not dissimilar to types found in the Rocky Mountains, but a great deal more altered. The next range to the east, the Logan Range, has a core of granite which extends at least as far southward as the upper canyon on the Frances River.

These mountains are from 60 to 100 miles north-west of the last, high western ranges of the Rocky Mountains and might possibly be considered the continuation of them, beyond a major downwarp in the structure, were it not for their greater deformation. The general north-westerly trend of these mountains is alone no proof of topographic correlation, because all structures in this part of British Columbia and the Yukon have approximately the same trend.

It seems conclusive that the Rocky Mountains die out on the south side of the Liard, with the exception of a range of limestone at the mouth of Vents River. Terminus Mountain, the last high mountain bordering the Trench, is composed of a thick limestone member that is truncated by the Trench. Other, intermediate limestone members cross the Liard without rising above the low, plateau-like surface.

The inference, which seems inescapable, is that the north-western, Yukon mountains are part of an older system, and that the Tertiary uplift, to which the Rocky Mountain system owes its being, dies out on the south side of Liard River. The Liard, which must be an antecedent stream, flows locally in canyons a few hundred feet deep. This figure is an indication of the amount of uplift, an insignificant amount compared to the uplift of the Rocky Mountains in general. There is no comparison between this small incision in a plateau-like region and the gorge of the antecedent Peace River through which the latter stream crosses the Rocky Mountains.

Cassiar Mountains

The Cassiar Mountains continue many miles to the north-west and south-east of the region. The backbone is underlain by granitic rocks and is about 1,000 feet higher in elevation than its flanking ranges and the western ranges of the Rocky Mountains. North-west of Mount Winston the easternmost range of the Cassiar Mountains is somewhat lower and less rugged than those elsewhere in the region. But this may be due to the softer character of the underlying rocks, rather than to a wastage of the mountains; certainly the resistant quartzite of the mount Winston range forms a series of prominent peaks higher than almost any others in the front ranges. Greater irregularity in structure and greater differences in rock composition account for the fact that the Cassiar Mountains are not made up of ranges as uniform or parallel as those that characterize the Rocky Mountains. The high, rugged front range flanking Fox River is composed of highly metamorphosed rocks, a fact that explains the physical character of this range as well as the fact that it is situated on an important divide.

Little is known of the actual limits of this mountain system. The north-eastern flank is apparently continuous and the south-western margin passes into high plateau country above which rise isolated flat-topped masses. To the south the Cassiar Mountains merge into what are sometimes referred to as the Stikine Mountains, of uncertain extent and orientation. Although within the region there is a centrally located batholith that forms a backbone, elsewhere the batholith is not apparently central.

The drainage pattern is in general haphazard, in marked contrast with the drainage of the Rocky Mountains. The headwaters of major rivers interlock and the Turnagain and Dease Rivers cut completely across the highest ranges.

Very little is actually known of the history of the northern Rocky Mountains or of the Cassiar Mountains, but it seems clear from observed features that the history of the latter system is more complex and that mountain building was initiated at an earlier date.

Rocky Mountain Trench

The Rocky Mountain Trench is a long, straight trough (see Plates I and II). It has generally been considered to extend the full length of the Province and for some distance into Montana. Throughout its known length it is a flat-bottomed valley with steep, straight sides, and is occupied

by rivers of major importance. Recent work by Lay* shows that the Trench does not persist as a continuous valley, but that in the region of the McGregor River and the headwaters of Parsnip River, there is no through trough. Here there is a change in trend of the Rocky Mountains, and each member of the Trench, projected, passes through low ground in which no major stream channel ever existed. If the Trench be considered as a structural feature quite apart from the fact that now, and for a long period of time, it has been a locus for major drainage, then there is no proof that the basic structure is not continuous, whatever that basic structure may be.

Theories as to the origin of the Trench have been summarized by Evans in the Brisco-Dogtooth area in the southern Rocky Mountains**. No single theory is adequate to explain more than a small section and the present writers have been unable to find any contributing evidence in the northern section, but it seems certain that there has been faulting along the line of the Trench, regardless of the effect of the Rocky Mountain uplift or the possible localization marginal to an old land mass; the nature of the faulting is unknown.

Recently completed topographic mapping (1939 and 1940) shows the Trench from Finlay Forks to Chee House, a distance of 260 miles, to be as straight as any feature of that length can possibly be. The straightness and uniformity is such as to indicate that the drainage has been initiated along a zone of structural weakness accompanied by faulting. The walls have undoubtedly been affected by faulting in comparatively recent (pre-glacial) times but the only positive evidence of faulting known to the writers is a scarp some 100 feet in height, on the west side of upper Fox River (see Plate I A); this has little significance other than to prove the fact of lateral movement supposedly Tertiary in age. Other evidence of movement is in the fact that the Sifton conglomerate, of Upper Cretaceous or Eocene age, that was laid down only in the Trench, has at a later date been much deformed, folded and drag-folded, while at presumably the same time the bordering older rocks have been sheared and deformed. There is, moreover, slight local evidence of a faulted relationship between the conglomerate and the older rocks on the eastern margin.

The Trench has commonly been considered as a marginal feature of the Rocky Mountains, i.e., as connected genetically with their formation. Certainly the Rocky Mountains are con-

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* Bull. No. 11, B. C. Dept. of Mines, 1941.

** Geol. Surv., Canada, Summ. Rept. 1932, pt. AII.

tinuous, while other mountain structures such as the Selkirk and Columbia Mountains are truncated at an acute angle by the Trench. The Rocky Mountains form, in many sections and particularly in the northern section, the smoother and more uniform wall of the Trench.

If the Trench is closely bound in origin with the Rocky Mountains then it should die out and disappear, if not at the exact termination of those mountains then within a short distance to the north-west. It is not known that it does terminate and the matter should be left in doubt, because there is some indication that the Trench continues. In the section at and immediately north of Chee House, the eastern wall of the Trench cannot be located with certainty against the low hills representing the almost completely wasted Rocky Mountains. Still farther north, there is no recorded evidence of a depression, but in the low land bordering the Liard River there is not sufficient relief to produce one, and there is no evidence that the Kechika or any other large stream flowed along this section. The underlying structure, however, could continue without being detected except by considerable detailed study. The eastern front of the Cassiar Mountains is continuous and passes west of the uppermost Liard River, a distance of at least 150 miles north-west of the end of the Rocky Mountains, and the straightness of the front suggests some structurally controlling feature, probably the Trench. The fact that the southeasterly-flowing upper Liard parallels the mountain front, strengthens this view.

Drainage

Drainage within the Rocky Mountains is by streams deeply incised in a trellis work pattern such as would be produced by long continued erosion of an elevated mass. The valleys show no modification by glacial erosion and the only abnormality is the incision of the streams in their lowermost sections adjacent to the Trench.

Drainage in the remainder of the region contains many abnormalities in the form of rejuvenation, stream-piracy and interruptions. Furthermore, a remnant of a drainage entirely superseded by the present stream pattern is indicated. There is, without doubt, a long and complicated stream history.

A through-valley extending from Sifton Pass, across Dall and Turnagain Rivers to Deadwood Lake has already been mentioned. Only fragments of this valley remain, as it has been deeply cut into and across by existing drainage, but it undoubtedly represents a former major stream valley, apparently draining northward and several hundreds of feet above present

crosscutting drainage. Other through-valleys exist which suggest, but do not prove the existence of an ancient drainage different from that of the present day.

Stream piracy, by headward erosion, has modified or reversed the flow of a number of streams. In some cases this can be proved, but in others it must be inferred. A clear example is given by the Fox River.

Fox River has captured the uppermost Kechika River from the region of Fox Lake to Sifton Pass, a distance of 10 miles. The evidence for this is that the benches flanking Sifton Pass extend south-eastward to abreast of Fox Lake and tributaries which swing northward across the bench at its inner margin swing southward close to Fox River. The capture took place in pre-glacial time because the upper Fox River has not been incised since the recession of the ice, but flows sluggishly through accumulations of drift. It is obvious that a stagnant lobe of ice occupied Fox River valley below Fox Lake, as evidenced by the depth and irregularity of the drift, but no glacial damming produced either the high benches or the one-time northward flow of the tributaries. On the contrary, the benches are continuous with the Kechika benches (see Plate I) and the northward-flowing stream sections, although short, are incised in rock in such manner and too deeply to be the result of glacial or post-glacial erosion.

The through-valley is incised by many of the streams flowing along its course, some of which are actively eroding headwards, and the valley itself is almost obliterated at a number of points by transverse streams. The most likely explanation of the latter fact is that the ancient stream was sapped by pirate streams from the upper Kechika, notably Rainbow and Frog Rivers and Denetiah Creek. The relation of the valleys of Dall and Turnagain Rivers is perhaps more complex, but piracy even by such streams is by no means impossible. Moodie Creek, a strong tributary of the Kechika, heads in lakes at a level comparable to that of the through-valley, and the stream flowing westward from this low pass is insignificant. Again, there is little to prevent Deadwood Lake (elevation 2,925 feet) from eventually being captured by a tributary of the main Mosquito Creek which, 6 miles distant, is 375 feet lower than the lake.

Piracy on such a scale is not frequently encountered but there is evidence in these latitudes of other piracies of equal significance, as in the case of Dease Lake valley which was formerly tributary to the Stikine and now drains northward. Johnston* even goes so far as to suggest piracy

* Geol. Surv., Canada, Summ. Rept. 1925, pt. A p. 45.

by an ancestral Dease River that virtually cut its way through the Cassiar Mountains by headward erosion. There is also some evidence that the Eagle River headwaters flowed into the Stikine.

There is some indication but no proof that part of the upper Turnagain River was tributary to the Stikine and has since been captured with a consequent reversal of flow to the north-east. If such is the case then the Turnagain River is not an antecedent stream but the headwaters on the western flank now drain through the mountains in a valley produced by a stream working headward from near Cassiar River.

The great bends of the middle and lower Turnagain form an abnormal pattern. The pattern of the Cassiar and Dall Rivers, with the connecting stretch of the Turnagain and the course of the combined water to Chee House is normal, as judged by the drainage pattern of the region as a whole, whereas the Turnagain flows south-eastward for some miles, then drops about 300 feet through a canyon to meet the Cassiar River and swings almost through a right angle. Another canyon-section immediately above Kutcho Creek drops the Turnagain at least 200 feet from a higher, widely-flaring valley.

Combine these abnormalities and suggestions of piracy in the Turnagain valley, and the history is obviously complex, but it must also be taken into account that in the upper valley, tributaries such as Wheaton Creek all enter the Turnagain valley over falls or through canyons and it is evident that there has been a considerable amount of pre-glacial rejuvenation of the master stream. The matter of rejuvenation of this section has been fully dealt with by Holland* , who estimates the indicated total amount of incision to be about 500 feet. On Wheaton Creek long continued erosion in the early Tertiary produced a mature topography in which the tributary streams entered the master river at grade. In the late Tertiary the Turnagain River was rejuvenated and began downcutting. This in turn initiated downcutting on Wheaton Creek, three stages of which are apparent and are represented by rock bench-levels along the creek. All are below the highest rock bench which represents the bottom of the Tertiary valley prior to rejuvenation. The rate of downcutting on the Turnagain was greater than on Wheaton and the other tributaries, consequently there is a hanging relationship between them and the main river, shown by the tributary streams entering the main valley through canyons and over falls or steep cascades. Subsequent glaciation has not greatly obscured this relationship and the pre-glacial dating of the rejuvenation is sig-

* Bull. No. 2, B. C. Dept. of Mines, 1940.

nificant because it supports an explanation greatly different from the alternative of over-deepening by glacial gouging in the bottom of the main valley.

The upper Kechika, from Sifton Pass to the canyon, is flanked by rock and gravel benches at a remarkably uniform height of almost 400 feet above the present stream (see Plate II). Although lower bench-levels occur, the upper level, developed chiefly on the north-eastern side and only locally on the south-western, is a continuous and very prominent feature. The bench is almost entirely gravel-covered but it is underlain by rock which is seen, in a few frontal cut-banks and in tributary canyons, to extend to the top of the gravel. A very few rock "islands" which project above the gravel are no higher than 30 feet above it. In short, the highest points of the irregular (eroded) rock bench almost exactly coincide with the blanketing gravel terrace. This composite bench, sloping gradually upward towards the flanking mountains, has the same down-stream grade as the present river. It is half a mile or more in width and occupies about one-half of the former bottom of the Trench.

This bench is left as the result of a pre-glacial rejuvenation or over-deepening of the Kechika valley. The surface of the rock bench is irregular, pointing to the fact that it was eroded prior to being covered by gravels.

The entrenched valley was blocked below Paddy Creek, particularly by moraines transverse to the Trench and which are as much as 1 1/2 miles in length. Boulder-clay is seen blocking the old channel at the upper end of the present canyon. The damming was approximately at the same level as the ancient valley-bottom, and behind the dam the entrenched valley filled rapidly with gravels brought in by the tributary streams. The river has subsequently cut through the moraine and bed-rock in a canyon somewhat east of the former channel, and has scoured the upper valley of gravels to its present outline. This scouring of gravels is not complete, and the bench front shows rock only locally. The tributaries in large part appear at this time to have re-cut their incised courses in the bench, but locally the streams eroding through the gravel veneer have cut new canyons in rock and gravels.

It is significant that the downcutting of the tributaries did not keep pace with the rejuvenation of the trunk stream, but the tributaries entered it pre-glacially, as at the present time, through canyons or even over falls. In other words, the hanging relation of the tributaries was brought about by rejuvenation and not by glacial erosion of the trunk valley.

The entrenchment of the upper river must have been brought about by a rejuvenation of the entire river system, and there should be evidence of the same or a similar bench-level flanking the lower Kechika and in the valleys of Frog and Gataga Rivers. There is no such evidence, and it must be assumed either that rejuvenation deepened these three valleys equally across their entire widths or that such a bench has been subsequently destroyed. It is believed that glacial erosion did not remove the bench (if it ever existed) in lower Kechika or Gataga valleys.

The history of upper Kechika drainage is complex and dates back over a long period of time. This applies also to the upper Turnagain, but it is impossible to correlate the two directly. Although the canyon-sections on Liard River prove entrenchment of that river and point to rejuvenation of the entire major river system, other influencing factors may easily have played a part.

It is not possible to explain the causes of the many obvious instances of pre-glacial changes in level or the changes in position and direction of flow of the major drainage system, and particularly to determine the time of their inception, but a suggestion of possible processes may be of value to future workers. First the indicated age of the drainage is great enough to have been influenced by changes in elevation of the Rocky Mountains in Tertiary time. Down-cutting of the Liard River across a moderate uplift has resulted in a rejuvenation that is bound to have affected the entire system. Other factors are possible faulting along the line of the Trench and possible uplifts in the Cassiar Mountains, with or without tilting. Piracy of Stikine River headwaters might be related to the great Tertiary modification of that drainage which undoubtedly resulted from the outpouring of tremendous quantities of lavas in the region of the Grand Canyon.

Whatever the causes have been, the present drainage system in the Cassiar Mountains has undergone many changes in Tertiary time. Discrepancies in elevation of about 500 feet between the master and tributary streams in the vicinity of Wheaton Creek alone point to the necessity for attaching major significance to stream history; the solution of the problems involves not only local causes but factors which may have affected the region as a whole. Glacial and post-glacial activity have, in many instances, made the solution far from easy.

Glaciation

Two types of glaciation must be recognized; alpine glaciation by cirque glaciers and numerous valley glaciers that extend from the summits for varying distances down the valleys and continental or ice-cap glaciation by an ice-sheet that covered all or nearly all the surface of the region.

The erosive effect of the former is to sculpture the higher slopes and summits and to modify the valleys to a U-form. The effect of the latter is less obvious and consists of rounding and smoothing the medium and higher slopes and also, in some cases, involves modification of the form of the master valleys. Both types deposit drift and moraines. It is believed that continental glaciation may partly obscure evidence of earlier alpine sculpture, and that later alpine glaciation will destroy or complicate the evidence of continental glaciation.

In the region there is much evidence of alpine glaciation in sculpture and deposition, chiefly in the Cassiar Mountains (see Plates V A and VI B). Depositional evidence of continental glaciation consists chiefly in the wide distribution of erratics and in accumulations of drift in the lower Kechika and Gataga valleys; erosional effects of the ice-cap are not so obvious, and in fact the presence of the ice-cap is only proved by its depositional effects.

Glacial erosion is not confined to the higher mountains that at present support small glaciers, but extends eastward to Fox River and to the high-level through-valley. East of this general line there is little evidence of glaciation in the Cassiar Mountains and even less in the Rocky Mountains. Except for the modification of the valleys of Frog River and Denetiah and Moodie Creeks, glacial erosion formed a few cirques on the eastern side of Mount Winston and other members of the same range; east of the Trench erosion produced only a few small cirques on the east side of Gataga and other high mountains.

Alpine glaciation was initiated in the high granite ranges and spread eastward with the formation of valley-glaciers that occupied all the easterly-flowing streams such as Ludwig and Jackstone Creeks, Rainbow River and others. These valley-glaciers reached the through-valley and spread and coalesced, but did not, generally, modify the valley outline. Some of this ice escaped by way of Dall River valley, and also, transversely, over the bench between Sifton Pass and Rainbow River and through the valleys of Frog River, Denetiah and Moodie Creeks. The flowing ice lost

erosive power in the Trench and its effect was mainly depositional. Lateral moraines in lower Frog River valley and transverse moraines in the Trench south-easterly from its mouth, prove that an easterly-flowing ice tongue did at least reach the Trench at this point. An ice tongue also travelled down Turnagain River and presumably reached the Trench.

Continental glaciation is believed to have been universal in the region. The general ice movement was eastward, as proved by the distribution of granite erratics as far as Rabbit River, 40 miles or more from the batholith; serpentine erratics also travelled eastward. It is not known in which direction the ice moved on the western flank of the Cassiar Mountains, although Hanson and McNaughton found evidence for a southerly direction.

The part of the ice-cap that flowed eastward from the high granite ranges overrode the region and must have filled the Trench and other valleys that were transverse to the direction of flow. At this time or stage of glaciation erosional effects were slight and the principal remaining evidence is depositional, although there must have been large quantities of drift brought into the Trench also by the transverse valley-glaciers.

The surprising or anomalous feature is the lack of erosion or modification of form of easterly-trending valleys in the Rocky Mountains and of similar smaller valleys on the Cassiar Mountain front. Although the rocks are so soft and well cleaved for the most part that normal erosion would soon obliterate small cirques, yet the evidence is so slight that it seems obvious that only local and small glaciers existed on the eastern sides of the highest summits.

GENERAL GEOLOGY

The bed-rock formations consist of great thicknesses of sedimentary rocks and a very small amount of volcanics intruded by a granitic batholith of major size. Besides the mapped volcanic members, thin bands of green schist and slate were observed at scattered localities but not sufficiently widespread to be mentioned separately elsewhere. The general formational strike is north-westerly. The field work having been distinctly a reconnaissance, the rock formations have been divided into large lithological units. Only a few, poorly preserved fossils were found, so the age of the rocks is largely unknown, and lithological correlation across the Trench is impossible.

The Cassiar batholith has already been named. The Sifton formation is a new name proposed for the conglomerate that occupies the bottom of the Trench south-eastward from Mount New, and that has been shown by Dolmage to be continuous far beyond the region, at least 95 miles south-east of Sifton Pass. Other members or lithological divisions are treated, not in order of age, which is unknown, but from west to east. Because of the lack of correlation across the Trench, the rocks of the Cassiar and of the Rocky Mountains are treated separately.

Cassiar Mountains

Member 1

This member consists of white, flesh pink and grey rhyolite flows, and rhyolitic tuffs and breccias. The dominant rock appears to be a flesh-coloured, highly-quartzose breccia, whose constituent feldspars are kaolinized but whose quartz is clear and glassy. The rocks outcrop in an elongated area about 8 miles long and 1 1/2 miles wide on the south fork of Mosquito Creek near the divide between it and Turnagain River.

This member appears to occupy part of a trough in the older Member 7 and though some of the volcanics dip westward their general structure is unknown. The general appearance and similarity to Tertiary volcanics elsewhere in the Province suggest that these rocks may be Tertiary in age.

Member 2

This member consists entirely of serpentine. On a weathered surface the rock may be greenish-grey, bright-green,

greenish-black or reddish-brown. In places the serpentine is intensely sheared, elsewhere it is massive and considerable variations are exhibited from place to place.

The serpentine outcrops in a belt ranging between 3 and 8 miles wide and extending south-eastward from Falls Creek near the head of the Turnagain across Wheaton Creek to the head of Ferry Creek. This belt may extend farther to the south-east, but its extent in that direction is not known. However, it does continue some 30 miles to the north-west as shown on Map 381-A of the Department of Mines and Resources, Ottawa.

Serpentine outcrops in one other area about a mile wide on the north side of Turnagain River about midway between Kutcho and Hard Creeks.

The serpentine evidently has resulted from the serpentinization of peridotite which is intrusive into the older Dease series.

Member 3 - Dease Series

The sedimentary rocks that lie between the western contact of the Cassiar batholith and the 129th meridian evidently belong to the Dease series as mapped by Hanson and McNaughton* west of that meridian. The series is predominantly sedimentary though it includes at least one volcanic member. It comprises black slate with a moderately well developed cleavage, black slaty argillite, thin beds of fine, grey sandstone and massive beds of light-grey limestone 5 to 200 feet in thickness.

The volcanic member is 3,000 to 5,000 feet wide and is made up of green andesitic flows and some associated fragmental rocks.

The rocks occupy a broad belt bordering the Cassiar batholith on the western side. Close to the batholith, and formed as a result of it, is a narrow belt of mica schist and quartz-mica schist. These rocks are the metamorphic equivalent of argillaceous rocks which away from the batholith are little changed except for the development of slaty cleavage.

The series as a whole strikes north-westerly and in large part dips to the north-east. However, insufficient knowledge prohibits outlining the major structure of the series where it is exposed on the upper Turnagain.

* Mem. 194, Bureau of Economic Geology, Ottawa, 1936.

No further data can be added regarding the age of the series which was indicated by Hanson and McNaughton as including much of the Palaeozoic from the Silurian to the Permain and possibly even the Triassic.

Member 4

This member consists chiefly of fine-grained massive granular greenstone and andesitic flows associated with a subordinate amount of fine-grained, thinly-bedded green tuff and brown and black slate and argillite. The rocks outcrop in a belt 4 to 5 miles wide flanking the Cassiar batholith on its eastern side near the head of Mosquito Creek. Although the andesite is intruded by the batholith it shows little or no alteration other than a slight increase in granularity near the contact.

The extent of this volcanic member to the south-east is not definitely known except that it does not cross the Turnagain River as a continuous belt, but apparently ends some 5 or 6 miles south of Mosquito Creek. Neither is its northwesterly continuation known with certainty, yet about 15 miles in that direction Hanson and McNaughton have mapped comparable volcanic rocks flanking the Cassiar batholith on its northeastern side. In spite of the fact that the rocks are not definitely known to be continuous, the close similarity of rock types and general relationship to the batholith strongly suggest that Member 4 be correlated with the McLeod series of the Eagle-McDame sheet. These rocks therefore are probably younger than the adjacent Member 7.

Member 5

This member consists chiefly of quartz-mica schist, also mica-schist, quartzite, and bands of limestone. It occupies a broad belt bordering the batholith and has not been recognized north of Dall River.

The coarseness of the schists and the degree of metamorphism are greater in the southern part, in the drainage of Ludwig Creek and Rainbow River. The mica is platy and garnets are abundant in some bands; locally the coarser quartzites are arkosic and the size of the feldspar grains suggests growth and recrystallization. Local bands are gneisses. Between Jackstone Creek and upper Dall River the metamorphism is less intense, there are no garnets and the mica is finer; even at the granite contact there are no coarse, gneissic phases except within a few feet of the actual contact. In the southern section the schist is folded, whereas in the northern section the schistosity is regional across a folded series.

Limestone members up to 200 feet in width occur in both northern and southern sections, also bands of impure calcareous rocks. These are the only horizons capable of correlation, but insufficient work was done to determine the structure.

On Flat Top Mountain and in the basin of lower Ludwig Creek dips are for the most part low, and the structure is one of broad, considerably warped and otherwise irregular flexures. Farther west dips are steep, and there is considerable minor contortion as well as major folding. North of Jackstone Creek dips are moderate on the average but there is some steep drag-folding.

Member 6

These phyllites, schists and argillites, with minor beds of limestone form a narrow band that wedges out at Ludwig Creek and widens on lower Rainbow River. The same rocks are found on upper Dall River where either the member is much wider or there are changes in lithology of bordering units of Members 5 and 7.

They are highly fissile, soft rocks, considerably crumpled for the most part, and it is evident that deformation has been localized in these incompetent rocks. The thin-bedded argillaceous sediments are converted to phyllites and glistening sericite schists laced with thin bands of limestone; on Dall River they are principally argillites. The structure is highly complex in detail, and the major structure is not known.

Member 7

In this member limestone is predominant. Large bluffs and entire mountains are composed of this rock, and interbands of slates, phyllites and argillites are subordinate both in amount and in topographic expression. The limestone is white to greyish and weathers to a light shade of buff or dirty white. The argillaceous rocks are thin-bedded and the limestone, although locally thin-bedded and slaty, is in general thick-bedded and massive.

The member is narrow on the south and widens at the termination of the Sifton conglomerate until, abreast of Valemont Mountain, it makes up the entire mountain range. It crosses the Frog River and continues diagonally across the Dall River valley as a series of prominent limestone ridges, the westernmost of which are truncated by the granite. In the southernmost section the member is tightly folded but on both sides of Frog River the average attitude is nearly flat, with abrupt warps and local major drag-folds.

Member 8

The division between this and Member 7 is not sharply marked. It is more a line on the western side of which the rocks are dominantly limestone and on the eastern side argillaceous and quartzitic, with a minor amount of limestone. The member is heterogeneous and changes in lithology along the strike.

The lower flank of Valemont Mountain and the lower parts of Frog River and of Denetiah Creek, are underlain by phyllites, argillites and impure gritty and calcareous sediments, for the most part thin-bedded. Three large bands of limestone are included, one of which forms a conspicuous wall several miles in length north of the mouth of Frog River. Prominent bands of quartzite on the western margin are seen north of Valemont Mountain. A band of heavy-bedded quartzite, several hundred feet thick, passes through Mount Winston and forms the backbone of a range with several summits well in excess of 7,000 feet elevation.

Changes in lithology along the strike affect the limestone and quartzite that would otherwise serve as markers throughout the northern part of the region. The massive limestone band at the mouth of Frog River plays out into thin-bedded, impure limestone north-west of Denetiah Creek, and the quartzite of Mount Winston, strong and prominent enough to form a high range of mountains, loses its identity somewhere south of Turnagain River.

The structure is very puzzling. There has undoubtedly been some overturning along either warped axes or along axes at an angle to the general formational trend. In addition, the softer and thinner-bedded rocks are much contorted. As a result the structure, and even the simplest outline of it, is obscure.

Member 9

This member consists predominantly of calcareous rocks, largely thick, grey limestone, thinly-bedded limestone and calcareous slate, calcareous argillite and a minor amount of black slate and thin sandy beds. In contrast to the other members this one, with the exception of some limestone beds, weathers to a fawn or pale buff colour. Much of the buff-weathering calcareous rock is believed to be dolomitic. The member underlies a width of but 3 miles on the low ridge to the north of Mount Winston, whereas farther to the north-west on the north side of Turnagain River it extends across a width of about 15 miles. Across that width individual for-

mations are repeated many times yet the detail structure is not known. The more massive units dip at low angles, whereas the thinly-bedded rocks are strongly contorted in minor drag-folds.

Fossils were collected from two localities, 1 and 2 miles south-east of the two lakes at the head of the south-west fork of Sand Creek. These were reported on by W. A. Bell, Chief, Paleontological Section, Mines and Geology Branch, Ottawa:

"Lot A:

Diphyphyllum sp.
Chonophyllum centre very fragmentary
Syringopora sp.
Bryozoa - at least two species
Atrypa reticularis (Linn) very small specimens
Orthis sp.
Gypidula 2 sp.

"This is probably a Silurian horizon. The fossils are so silicified that structure is lost. Gypidula is perhaps more common in the Devonian, but several species occur in the Silurian. The Orthis is a Silurian type.

"Lot B:

Zaphrentis 2 sp.
Favosites sp.
Halysites cf gracilis Whiteaves
cf Protarea sp.
cf Columnaria alveolata Goldfuss or Favosites sp. A poor preservation of structure in one spot suggests the former.

"One of the Zaphrentis and the general association of these species suggest an Upper Ordovician horizon of Richmond age."

Other similar fragmentary fossils were seen north-west of Sand Creek and also near the main fork of Mosquito Creek.

Rocky Mountains

Member 10

Volcanic rocks are exceedingly rare in the Rocky Mountains, yet this member comprises massive, fine-grained, green volcanic flows, cleaved, fine-grained, thin-bedded green tuffs, sheared and altered coarse volcanic breccias and a very minor amount of thinly-bedded argillaceous tuffs. Near the peak of Gataga Mountain the rocks are cut by narrow, red jasperoid veinlets,

and along the front of the mountain near their contact with the adjacent sediments the volcanics are intensely sheared and altered to talc and rusty-weathering carbonate. Elsewhere, however, the flows are more or less massive and retain their amygdaloidal and porphyritic texture.

This member outcrops in a lens about 8 miles long and 2 miles wide mainly on the front of Gataga Mountain, and appears to be an infold into Member 14. Although the rocks are similar to Member 4, no correlation of the two is possible.

Member 11

This is a slaty, calcareous member of considerable apparent thickness flanking the Trench on the east and extending as far north as Kechika Canyon. The rocks are light to medium grey in colour and are characterized by being highly cleavable. They are dominantly argillaceous and calcareous paper-thin slates, poor grades of phyllites, and slaty limestones. Massive bands of limestone are minor in amount. The ready cleavability results in ravelling of outcrops and the production of great quantities of talus and of a thin cover of cleavage fragments.

The average dip of these rocks is north-eastward at moderate to steep angles, but there is much minor contortion. The thin-bedded rocks are folded and crumpled, across which a superposed cleavage gives, in many cases, a high degree of fissility. There has been more than one period of deformation, the effects of which are most marked closest to the Trench but extend at least as far eastward as the summits of the first range. The second deformation has refolded the rocks, a refolding accomplished through the cleavability; there is not merely a simple folding of the cleavage planes but a contortion and locally a mashing of the whole rock mass.

Member 12

This member is characteristically gritty, and is made up of siltstones, sandstones and less limestone and shale. It forms a reddish-weathering range, of which Mount New is the most prominent summit.

The gritty or silty rocks are rather incoherent and produce much fine, reddish talus. Two varieties of quartzite occur as locally prominent bands; one is fully recrystallized, vitreous white quartzite of a high degree of purity, and the other, for some reason is a poorly cemented rock made up almost entirely of fine, well-rounded and pitted sand grains. Intermediate types and some argillaceous slates are also present. There are some limestone bands, but few calcareous slates.

This member appears to be synclinal and the peaks of the range are aligned along the axis of the syncline. Complete confirmative evidence was not obtained, as there is considerable local contortion, but the dips of Members 11 and 13 are towards this member and are seemingly continuous beneath it.

Member 13

This member is very similar to, if not identical with Member 11. If Member 12 is the bottom of a major syncline, then the two are identical.

The only difference between Members 11 and 13 is that there are less phyllites and highly-fissile, papery slates in the latter. There is also more flaggy, calcareous slate and slaty limestone in the eastern part of Member 13, but the central part is dominantly argillaceous slate. The absence of true phyllites may be due to the lesser amount of deformation eastward or away from the Trench; certainly there is less mashing and folding of the cleavage than in the rocks of Member 11 that border the Trench.

The dips are, in general, steep towards the west, but with local contortion and some drag-folding.

Member 14

This member is composed dominantly of limestone in thick bands between which are bands of argillite, phyllite and quartzite. The average dip is steep to the south-west.

The limestone forms a high, castellated range that is crossed by Gataga River and ends in Terminus Mountain, where the last of the limestone is truncated by the Trench. This range contains the highest peaks in this general section of the Rocky Mountains. The baldness of the range, and the fact that frontal slopes are all limestone (many of them dip slopes) gives the impression that the member is nearly all limestone, but actually the amount is only about one half.

The limestone is for the most part light grey or white, and is heavy-bedded, but on Brownie Mountain there is some associated quartzite in thin bands and the limestone itself contains quartz grains; this rock weathers to a buff colour. Bands of limestone and bands of argillaceous rocks, each several hundred feet thick in most cases, alternate throughout the member. The argillaceous rocks are locally, or in some bands, altered to glistening phyllites; such bands underlie depressions and lateral valleys between the ridges of heavy-bedded limestone.

Member 14 is truncated by the Trench, and it is in this section that the regular relation between the line of the Trench and that of the Rocky Mountain structure is best seen. Ridge after ridge reaches the river at and below the Gataga River mouth and disappears, and with the last one, through Terminus Mountain, the boldness and height of the Rocky Mountains disappear.

Member 15

This member is of broad extent and underlies the whole of the explored part of the region north of Terminus Mountain and east of the Trench. The lowness of this section might be explained by the softness of the rocks if it were not for the fact that east and south-east of Brownie Mountain the same rocks underlie high rounded ranges that attain elevations of 7,000 feet.

The member is composed of grey, black and chocolate-coloured slates and argillites, with minor amounts of limestone and quartzite. The structure has not been worked out. One prominent limestone band near the western margin forms a canyon on the Gataga River and extends north-westward from that point as a high, serrate ridge. This member apparently does not persist, as it is not recognized farther to the north-west, though another limestone bed was observed south-east of the mouth of the Turnagain River.

Cassiar Batholith

This is a batholith of great length, known to be 150 miles long and, if it extends from Teslin Lake to the Omineca, 400 miles. The width, including pendant areas, is 20 to 25 miles in the Eagle-McDame sheet to the north-west, and as much as 30 miles bordering the upper Turnagain. The batholith was not crossed south of the Turnagain, and only the eastern contact has been mapped. From the headwaters of the Frog River to those of Ludwig Creek the contact is mapped only approximately, and was not actually reached in 1940; its position on the accompanying map is believed to be accurate within a mile or two.

The rock is all quartz-bearing and light in colour, with a small amount of dark-coloured minerals, chiefly biotite. The dominant type is granite, but there is also granodiorite and some quartz-diorite. Perhaps the commonest rock type is a pink granite or porphyritic granite, of rather coarse grain which, when prominently porphyritic, contains orthoclase phenocrysts up to 2 inches in length. Another type, probably a border phase, is a medium to fine-grained grey, speckled

mica-granite. A third type, one occurring in the southern part, is a grey to white porphyry, quartz-bearing and with little or no pink orthoclase.

In the section of the upper Turnagain the contact is irregular, and from a width of 30 miles on the north side of the Turnagain River the outcrop of the batholith narrows to 15 miles between the southeasterly-flowing stretch of the river and Kutcho Creek. The eastern contact at the head of Mosquito Creek appears to dip at a low angle to the east. A roof pendant several square miles in extent was observed between the head of Mosquito Creek and the mouth of Three Forks Creek and at least one other was seen several miles to the north-west.

Nothing is known of the actual contact in the southern section nor of the western contact other than that it swings eastward between Hard Creek and the mouth of Kutcho Creek.

One outlying body is south of Ludwig Creek. about 9 miles east of the batholith and 6 miles west of the Trench. Several other outlying bodies of diorite and quartz-diorite outcrop near the head of Wheaton Creek, and Mandy* observed two granitic bodies east of the mouth of Ferry Creek. Dyke offshoots from the batholith are rare. A great variety of dyke rock, probably directly or indirectly related to the batholith, is found as float in many streams; these include all sorts or porphyries, mostly fine-grained, and from light to dark in colour. A dyke of diorite occurs on lower Rainbow River near the Trench, and a similar dyke is on the mountain north-west of the lower bend in Denetiah Creek. Andesite porphyry dykes are seen east of the batholith and south of the two lakes at the head of Sand Creek; small mica lamprophyre dykes occur near the isolated body south of Ludwig Creek.

Pegmatites are abundant in the southernmost part of the region but are rare or lacking in the northern part. A few pegmatitic phases of the granite occur in the Turnagain section, and the same is noted in the Eagle-McDame map-area. but there is no abundance of pegmatite dykes in the surrounding rocks. In the mountains abreast of Sifton Pass and in the basin of lower Ludwig Creek there is an abundance of pegmatites and small bodies of strongly pegmatitic granite. A few pegmatites also were seen in the mountains west of the north-westerly-flowing stretch of Rainbow River. It is a significant fact that the schists of Member 1 are coarser and more fissile (locally garnetiferous and felspathic) in this southern

* Ann. Rept. Min. of Mines B. C. 1933 pt. A, p. 65.

section where pegmatites are abundant than in the northern section where pegmatites are virtually absent.

Sifton Formation

This is named the Sifton formation because it is seen to advantage for 10 or 15 miles north and south of Sifton Pass. It occurs within the Trench and locally to elevations of about 5,000 feet, or 2,000 feet above the valley floor.

The formation is composed almost entirely of conglomerate, with local, minor beds of sandstone and shale. The conglomerate is strongly cemented and is a hard, resistant rock, but on weathering tends to break down so as to free the constituent pebbles. The sands and shales, locally strongly carbonaceous, are for the most part weakly coherent.

The pebbles of the conglomerate are well rounded and in rare instances are as large as an orange. The common size range is between that of a hazel nut and an egg. The matrix is finely conglomeratic or sandy. Constituent materials are all sedimentary, among which limestone is always present and predominates locally; in some of the exposures, the proportion of limestone is 8 to 1 and the matrix is calcareous. Other pebbles are shales, sandstones, argillites, quartzites and cherts; some black chert pebbles, commonly rather small, are everywhere present. No igneous pebbles are found and none of schists or rocks metamorphosed beyond the grade of phyllite.

Plant remains are numerous in the sandy beds but are fragmentary and poorly preserved. One collection of fossils was submitted to W. A. Bell at Ottawa who states:

> "There are only several fragments of dicotyledonous leaves present, and none is sufficiently complete for identification. The best is seemingly a Viburnum, not surely referable to any described species. There is a single small, poorly preserved fragment of a fern, again not certainly identifiable although comparable to Asplenium? coloradense Knowlton or to Asplenium? magnum Knowlton. The bulk of the collection consists of twigs of a Sequoia, probably belonging to the same species as one recorded by Hollick from the Upper Cretaceous Chignik formation of Alaska ..... But I do not consider that an age determination can be safely made on such a slender basis and the best that may be stated is 'Upper Cretaceous?' A Paleocene or Eocene Age is a possibility."

Coal seams occur but none were seen. One, west of the Kechika above Rainbow River, is said to be several feet wide. Another seam in the lower canyon on Driftpile Creek is covered at high water, but a sample and description were obtained by G. Emerson of the topographic party in September. This seam is 3 feet wide at water's edge, strikes north 70 degrees east and dips 75 degrees northward; the coal is poorly coherent and has a strong odour. An analysis showed moisture, 3.3 per cent; volatile combustible matter, 24.5 per cent; fixed carbon, 57.3 per cent; ash, 14.9 per cent; B. T. U.'s 11,857. This, and other coal found on the river bars near Rainbow River is lignitic and burns with difficulty.

The formation has been strongly deformed. The basin has been compressed laterally, with the production of steep dips, irregular folding and some drag-folds and shearing. The beds are clearly unconformable with the underlying rocks and there is evidence of faulting on several observed contacts on the eastern margin. No idea of the thickness was obtained.

Glacial Drift and Alluvium

The bottom of the Trench, from near the mouth of Frog River north-west, is mapped as glacial drift and alluvium although a few minor rock points are seen on the river's edge. This serves to show the approximate margins of the Trench bottom. Elsewhere, as in the upper Kechika, the drift and alluvium are too narrow to be mapped separately.

The drift consists of morainal deposits only in the angle of Gataga fork, and elsewhere comprises stratified and semi-stratified gravels and a minor amount of boulder-clay. Pot-holes and similar irregular surface features occur locally, and it is believed that much of the valley-fill has been worked over and at least partly modified by stream action. The alluvium consists of gravel bars and of gravel and silt banks amongst and adjoining the braided channels.

STRUCTURAL GEOLOGY

The following discussion deals with broad generalities in such a manner that the analysis may be of service to future field workers. The solution of major problems of correlation, particularly concerning the age and physical relationship between the rocks on either side of the Trench, is dependent on age determinations, and fossils were found only in the Sifton formation and in Member 9.

The region is profoundly folded, and there is a difference in character of folding in the two mountain systems. The Trench constitutes a boundary line across which lithological correlation has proved impossible, and the reason for this fact, together with that of the origin of the Trench, is a problem of first importance. There is at present no solution of this problem, which must wait at least until the stratigraphy of the region is well understood.

The sedimentary rocks of the Rocky Mountains are all steeply dipping and the folding is rather tightly compressed. The structural trend is approximately north 40 degrees west and meets the line of the Trench at an angle of 10 degrees. This trend, and the implied structure, is so uniform that the lines of exposure of prominent members such as 14 and 12 are almost perfectly straight. Cross-flexures are small and insignificant. The only apparent major fold is the syncline involving Member 12, which presumably makes Members 11 and 13 equivalents. However, it is believed that this syncline is really only a large drag-fold, and not a principal axis. The failure of the limestone of Member 14 to appear on the edge of the Trench at the southern end of the region or even far down Fox River, and suggestions of overturning between Gataga and Terminus Mountains, strongly indicate that the structure is one of narrowly compressed drag-folding on a major scale, in spite of the fact that no such structures were actually seen or worked out.

Minor contortions and drag-folds are numerous in the softer rocks, even if stronger bands are continuous and straight for great distances. As a matter of fact large areas of slates and phyllites are complexly folded within a single general horizon. Cleavage is present in all but the more massive limestones and quartzites and is developed to a high degree of perfection in most of the softer rocks. This is regional flow cleavage, parallel to the axial planes of the folds and parallel to the beds or nearly so throughout much of the closely folded formations, but superposed across contorted areas without regard to bedding. This suggests deep and close folding.

There is evidence of more than one period of deformation in the folded cleavage and local mashing found close to the Kechika and along the margin of the Trench.

Folding in the Cassiar Mountains is not nearly so uniform. There is a general structural trend of about north 50 to 55 degrees west but individual folds are far from regular. Anticlines and synclines, at one locality seemingly continuous and of major importance, are at other localities interrupted by cross-flexures, lose their identity, or are so complicated by drag-folding and thrusting that they pass into other structures.

All the rocks except the massive limestones and most quartzites possess secondary flow cleavage which is developed to a high degree of perfection in the thin-bedded argillaceous rocks. It is developed regionally but, due to the complexity of the folding is not everywhere parallel to the axial planes of the folds.

Drag-folds are seen on scales measurable in a few feet to 1,000 feet, with some overturning, that represent overthrusting from the west. Even larger-scale overturning is indicated and this seems to be the reason why it was impossible to determine the succession or to explain the general structure in any reasonable completeness.

The schists of Member 4 are openly and irregularly folded in the south about Flat Top Mountain and almost as openly folded north of Jackstone Creek, but large drag-folding seriously complicates the outlines of these folds. The schistosity is folded in the southern locality. Member 6, composed of incompetent rocks, is so deformed that the structure is not readily understandable. Member 7 is of wide distribution but is not believed to be very thick, possibly 3,000 feet; compressed into a repetition of folds abreast of the Sifton conglomerate, the structure appears to open out to the north-west and the average or regional attitude is almost flat. This is best seen in the mountains cut through by lower Frog River, where the flatly-warped beds are caught up into local asymmetrical folds, some of which are the expression of thrusting from the west, but others are simply irregular contortions of no apparent meaning.

The generally incompetent rocks of Member 8 are, particularly in the southern section, strongly contorted and the structure is not simple. The weaker argillaceous to calcareous bands are minutely rumpled and drag-folded between the stronger, competent bands. The prominent limestone rib at the mouth of Frog River and the southernmost end of the quartzite member dip steeply westward, but the dip of the

same quartzite on Mount Winston is 40 degrees eastward into an apparent syncline of which the eastern limb is in the easternmost range about Moodie Creek. The only explanation for such anomalous dips and the failure of the quartzite to be repeated is that the structure is overturned and plunging. This explanation puts Member 8 below Member 7 and supposedly the equivalent of Members 5 and 6 which lithologically, is not so. Changes in lithology over a distance of several miles might account for the difference, and certainly both the limestone and quartzite bands tend to play out along the strike to the north-west.

The rocks of Member 9 dip, in general, to the west, with strong minor contortions. There is probably a considerable amount of repetition in this member.

There is much definite evidence in the Cassiar Mountains of overturning in the complex structure. The overturning is in most cases no more than a few degrees from the vertical, as seen in drag-folds, large and small, produced by lateral compression or overthrusting from the west.

In the Rocky Mountains overturning is deduced. Although no structures were worked out, there is evidence of tight folding in sections of regional parallel dips. There would then appear to be, of necessity, overturning to the east in Member 14 which is supposedly beneath Members 11, 12 and 13. The non-appearance of this limestone on the wall of the Trench south of the region further points to some asymmetrical major structure. Nevertheless it cannot be said that there is, from the cited overturning, regional evidence of overthrusting from the west.

No evidence of faulting was seen although the scale of the work was such that only major offsets would be noticed. However, major faulting could occur parallel or nearly so to the regional structural trends and its presence might be hard to detect without a better knowledge of the stratigraphy. It is at least suppositional that the Trench is a line of structural weakness and involves faulting or combined folding and faulting, originally of great age and probably repeated. It is possible that lateral or sympathetic faulting took place parallel to the Trench as slicing of the structures at oblique angles.

A feature of major importance is the varying degree of metamorphism in Member 5. As stated, these schists in the southern part of the region are considerably coarser than in the northern part of their extent. Mica plates are larger, locally the size of a thumb-nail; garnet is prominently developed and the rock locally is a gneiss. In the northern

section the mica is in small plates and schistosity, amounting commonly to no more than an advanced stage of slaty cleavage, is developed regionally across the bedding; garnet is not seen in hand specimens.

This difference in degree of metamorphism is directly related to the presence of pegmatites in the southern section and probably to the mapped granitic stock. About 15 miles south of the region, in Fox Pass, the metamorphism is more intense and the rocks are intruded by many dykes and small irregular bodies of granite. In this section the sediments have been converted to felspathic and garnetiferous gneisses and are strongly contorted. Few pegmatites were seen in the small area examined, but there is much fine-grained faintly pinkish granite, in very irregular bands and masses measuring from a few inches to tens of feet in width. The granite crosscuts and also follows the foliation of the rocks and has produced in some places an intrusion breccia.

Although the main batholith is about 20 miles west of the Trench in the section between Ludwig Creek and Fox Pass the effects of intrusion are obvious in the production of gneisses and schists and in the irregular introduction of granite and pegmatite dykes and masses. No such effects are seen flanking the batholith from Jackstone Creek to McDame.

In short, the effects of intrusion spread about 20 miles east of the main batholithic contact, or rather the projection of it in the south and have little noticeable effect in the north, where even contact metamorphism is closely confined. The minor intrusives have a counterpart far to the south in the many pegmatites of the Butler Range west of Finlay River*.

Little is known of the structure of the Trench in the portion examined except that it is an old one. The presence within it and not elsewhere of the Sifton formation of Upper Cretaceous or Eocene age proves this. The Trench probably follows a line of structural weakness along which faulting has occurred. There is a suggestion, not proved, that some faulting occurred at comparatively recent date along a scarp several miles in length on the western flank abreast and north of Fox Lake (see Plate I A). This is at least 100 feet in height and is seen to be continuous, if only fragmentarily preserved. It is believed to be a fault scarp of pre-glacial age and to be related to the last structural adjustment of the Trench.

* Geo. Surv., Canada, Summ. Rept. 1927, pt. A, p. 28.

ECONOMIC GEOLOGY

Placer-gold deposits have been worked on Wheaton and Walker Creeks but there has been no continuous production from any other creeks in the region. A few lode deposits are known but they have not been developed. Discussion will therefore be restricted to generalities, with brief mention of a few known mineral deposits.

Placer Deposits

The deposits on and near Wheaton Creek have previously been described in detail*. In 1940 the drag-line operation continued on the Peacock lease and a small gasoline shovel was operated down-stream on the Elvira and Ryan leases. Some prospectors were active in the general locality and work continues to be done on Faulkner (Palmer) Creek though as yet no pay-gravel has been found.

Walker Creek, discovered in the spring of 1877, has not received any attention for many years. At that time it was stated:**

> "The prospect obtained has been a very fair one: For an aggregate of 48 days' work some 60 ounces of gold dust were taken out, realizing from $18 to $21 a day to the hand. The gold is fine, of a granulated appearance, and heavy quality--the largest piece obtained weighing not more than fifty cents. Mr. Walker and party found that the creek prospected for about 2 1/2 miles about the same as the ground they had worked. The creek is about 6 miles long and the average width is 200 feet, depth to bed-rock (slate) 7 to 12 feet, no benches, with sloping banks."

However, the next year, 1878, the Gold Commissioner reported that "the hopes entertained last year with regard to the discovery by Mr. Walker of a new creek, have, unfortunately not been realized," in spite of the fact that $35,000*** worth of gold was recovered. Gold worth $24,000 was recovered in 1879 after which date the production declined sharply, and in 1882 one white man and six Chinese recovered only $2200. In the last recorded year, 1887, 5 Chinese still continued work though they recovered only $1000. Since that time the creek

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* Bull. No. 2, B. C. Dept. of Mines, 1940.

** Ann. Rept., Minister of Mines, British Columbia, 1877.

*** Walker Creek gold was valued at $19 an ounce.

appears to have received little or no attention.

The creek, which is between 5 and 6 miles long, flows in a south-westerly direction into the south end of Deadwood Lake. For about 2 miles up from its mouth the creek flows on about a 2 per cent. grade and appears to be almost completely worked over. There are many rock-piles, old sluice-boxes, whipsawn lumber and the remains of 15 log cabins. For a mile farther up-stream the creek-bottom has not been worked so extensively, but there are signs of its having been prospected by shafts to bed-rock. In that stretch the grade steepens to about 5 per cent. and the bottom narrows to about 100 feet in a more canyon-like valley; there are more large boulders and it appears that the pay-streak did not justify working.

In the autumn of 1940 three prospectors were encountered on the trail, who intended to do some work on the creek. It seems likely however, that the lower stretch has been thoroughly worked out and possibly only a few small unworked patches of deeper ground could be salvaged. At the old price Walker Creek gold sold for $19 an ounce, so at the present rate wages might be made on the upper stretch; however that possibility remains to be proved.

Walker Creek heads in a belt of grey slate containing many quartz stringers and veins. The slate belt which is about half a mile wide extends south-eastward and crosses by the second lake at the head of Sand Creek. If the placer-gold were derived from the quartz veins then other creeks which cross the slate belt might warrant prospecting for placer.

Accounts in the Annual Reports of the Minister of Mines for 1886, 1887, 1894 and 1906, indicate that in those years parties of prospectors had been on the Kechika and upper Turnagain Rivers. At that time fine gold was found at low water on bars on the Kechika and men working with rockers on various bars, took out good pay for short times. Recently, two men are reported to have recovered 10 ounces of fine gold from a bar on the Kechika below the mouth of Frog River.

It is not known how much of the remainder of the region has been prospected, and although it is probable that prospectors have been on many of the creeks in the Cassiar Mountains, it is safe to say that the search has probably not been thorough.

It is not likely that placer-gold will ever be found in quantity in the Rocky Mountains. The sedimentary rocks do not appear to be mineralized and the effects of igneous intrusion

are confined to the western side of the Trench.

Streams flowing east of the batholith in the Cassiar Mountains traverse rocks that contain evidence of mineralization. The western part of this section has been heavily glaciated and some streams have cut rapidly in gorges, others head in high glacial basins and fall in cascades to the larger valley bottoms; trunk streams flow rapidly in canyons, or sluggishly over deep valley-fills of glacial material. Some creeks, particularly in the eastern part of the same section, have not been modified by glacial action and a few may represent the continuous, prolonged erosion which seems necessary to produce placer concentrations.

The factors that have produced and permitted the retention of placer-gold concentrations have elsewhere been enumerated in the case of Wheaton Creek (see page 27). To summarize, Wheaton Creek crosses a belt of slate containing numerous quartz veins. The gold released by erosion of the quartz veins, during the early Tertiary, was concentrated in placer deposits in the stream bed of the ancient valley. In the late Tertiary, but pre-glacially, Wheaton Creek was rejuvenated and the stream incised a canyon that extended for 4 miles above its mouth; the originally concentrated placer-gold was at this time reconcentrated in favourable stretches in the canyon. During the Pleistocene the valley was occupied by ice and was to a small extent eroded and modified by it, yet the position of the placer-gold in the bottom of the canyon saved it from being dispersed by ice movement. Any gold which may have been left on higher exposed rock benches was swept away. The post-glacial Wheaton Creek has re-incised its course in the late Tertiary canyon and has eroded much of the glacial fill so that the present depth to bed-rock in most places is not greater than 30 feet.

The same conditions and sequence of events, or approximately the same, may obtain in other parts of the region, inasmuch as it has been shown that glaciation has been widespread and that regional rejuvenation or incision of stream valleys took place pre-glacially. Consequently, further placer prospecting in areas of favourable rocks should be undertaken with a full appreciation of the stream history and in the light of what is known definitely.

Lode Deposits

Knowledge of early lode discoveries is scanty but in past years interest was naturally, and for good reasons, centered on placer. Yet in 1898, Inspector Moodie states "at the lake (Deadwood Lake) I found Mr. Walker (possibly

the discoverer of Walker Creek) and a companion, prospecting for the C. C. R. Company (the Cassiar Central Railway Company). They have found some good prospects of both gold and copper in quartz."

Furthermore, in the Annual Report, Minister of Mines, British Columbia, 1906, it is recorded that a party of prospectors set out from McDame and travelled about 80 miles south-eastward into the Turnagain section. Some claims were staked and recorded and it is stated that the quartz assayed well in gold, silver and copper but nothing further is known.

A copper deposit is reported to have been staked years ago on the lower Gataga River, and in 1940 a copper discovery was made and staked in Hidden Valley Creek, tributary to Turnagain River between Mosquito and Sand Creeks. Neither of these deposits was seen, but a verbal description of the discovery on Hidden Valley Creek was obtained.

No mineral deposit was seen in the Rocky Mountains, and little evidence of quartz veining. Copper is reported to occur east of the Finlay River, far to the south of the region, but in general these mountains have not proved to be well mineralized. Throughout the Rocky Mountains there is fairly widespread and prominent veining by calcite, for the most part in small and discontinuous stringers, and a few of these veins contain a minor amount of quartz that is not mineralized. A few quartz veins were seen east of Gataga River in the lower 15 miles, and a few east of Gataga Mountain, but no mineral was seen in them. A search was made in this section for the reported copper deposit but without success.

In many parts of the Cassiar Mountains quartz veins were seen, almost exclusively in the non-calcareous rocks. Most veins contain ankerite, or rusty-weathering carbonate.

Glassy white quartz veins are numerous in the coarse-grained schist about Ludwig Creek. Irregular veins containing pyrite occur in the crumpled rocks of Member 5 on Rainbow River. Float containing pyrite and a little chalcopyrite was seen near the mouth of Rainbow River, and in parts of the front range to Frog River, and one small vein containing chalcopyrite was seen on the mountain north-west of Paddy Creek. Quartz veining containing pyrite, chalcopyrite and galena was found 7 miles south-west of the mouth of Denetiah Creek. Quartz veins were seen south-east of the lakes at the head of Sand Creek and also copper float below the mouth of that creek on the Turnagain. Some quartz float was seen north-west of Jackstone Creek.

On the eastern shore of Dall Lake a small bluff at water's edge is composed of intensely silicified limestone and contains many small stringers of chalcopyrite.

The discovery on Hidden Valley Creek is reported to consist of chalcopyrite mineralization across widths as great as 40 feet, and traceable for 2000 feet. The gangue appears to consist of ankerite and quartz, and a little galena occurs locally. No further data are available.

It should be noted that the batholithic contact makes a sharp bend abreast of Dall Lake. The country adjacent to or radial to this bend should make good prospecting ground for some miles, particularly as there is in it a considerable diversity of rock types and structures.